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Automatic detection of boundary layer height using Doppler lidar measurements

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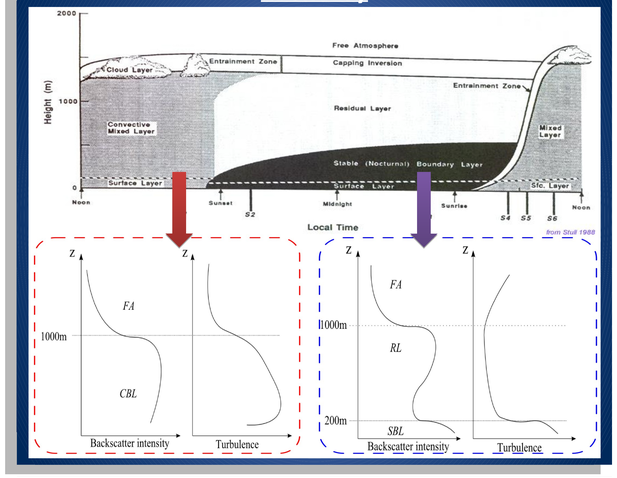
Purpose

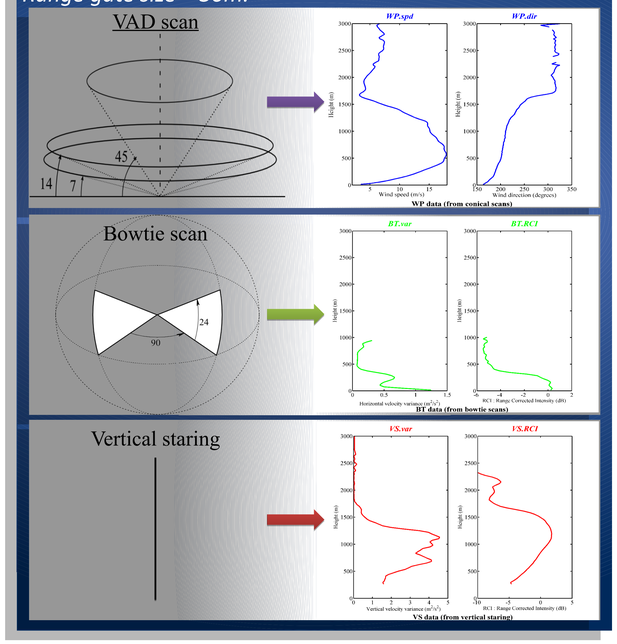
Boundary layer height (BLH) is an essential parameter for air quality research, and forecasting. Doppler lidars provide continuous information such as wind speed and direction, turbulence information and backscatter intensity with high resolution (both spatial and temporal). This work aims to find an algorithm able to automatically detect the BLH using all the lidar-measured variables. Two methods will be presented : one based on peak detection, one based on cluster analysis.

1. Theory



2. Data

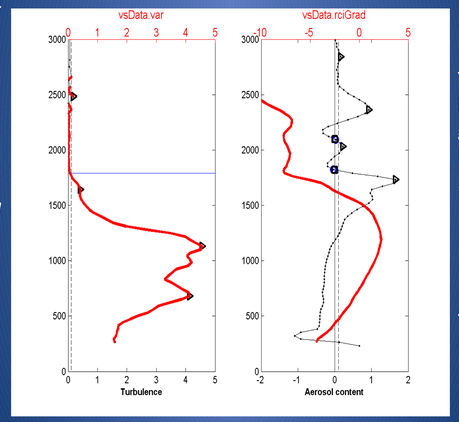
From campaign : TXFlux – Texas Flux Study
Period : Mar, Apr, Oct, 2013
Main goal of the campaign : Study the methane emissions fluxes downwind of oil/gas large fields.
Type of lidar : HRDL – *λ=2µm, PRF=200, Data rate=2Hz, Range gate size = 30m.*



3. Peak detection method

Idea : BL top is a transition between BL and free atmosphere (FA). We identify peaks in both the turbulence and the gradient of the aerosol backscatter profiles.

Two types of profile



Peaks connected to the ground

Turbulence must maintain high values all the way to the ground.

1) *Define a peak-based threshold*
2) *Look for the highest point above the threshold*

BLH = highest point connected to the ground

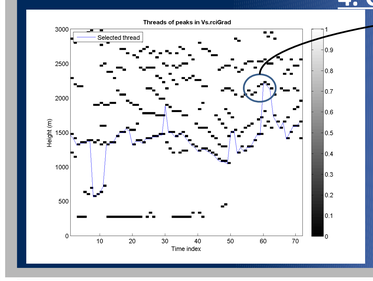
Peaks that track a transition

Transitions such as BL top are peaks in gradient of aerosol backscatter profiles.

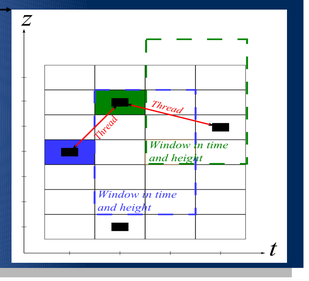
1) *Compute the gradient profile with Haar wavelet transform*
2) *Record peaks in gradient profile*

We choose among the peaks with a *continuity test.*

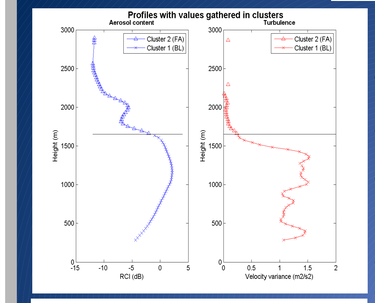
4. Continuity test

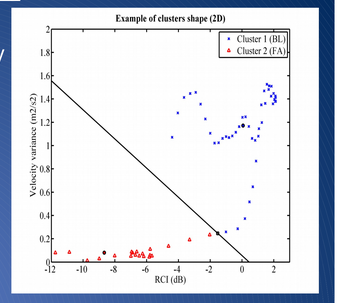


For each peak, we look for neighbors in a window of height and time. All the peaks in the same window are linked together by a *thread.*



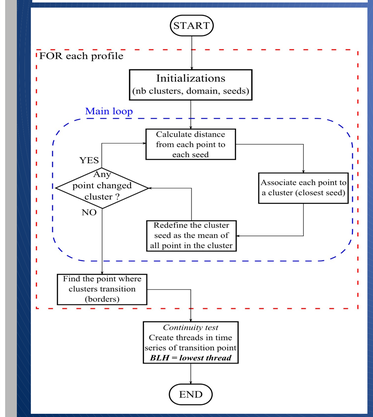
5. Cluster analysis





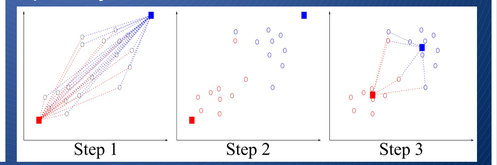
Idea : BL air is characterized by
- *High turbulence*
- *High aerosol content*

We track the BL air by gathering these high values in clusters



Algorithm : "K means" (non-hierarchical clustering). Used mainly in data-mining.
From : Toledo et al. (2013)*
Description : Iterative algorithm with three steps in the main loop :

1) *Calculate point-to-seed distances.*
2) *Link each point with its closest seed.*
3) *Redefine the seed.*

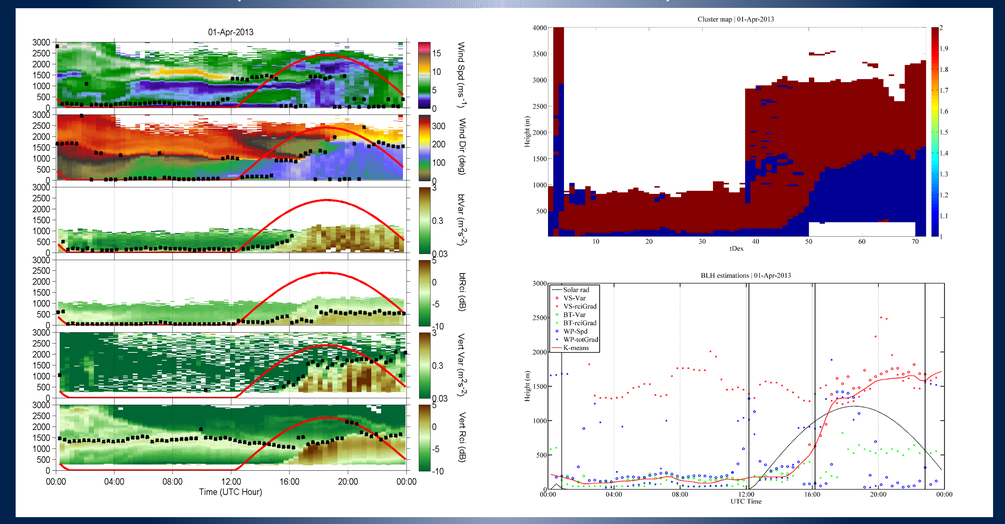


***Reference :** Toledo D. et al. (2013): Cluster analysis: a new approach applied to lidar measurements for atmospheric boundary layer height estimation. J.Atm.Oceanic Tech, **31**, 422-436.

6. Results

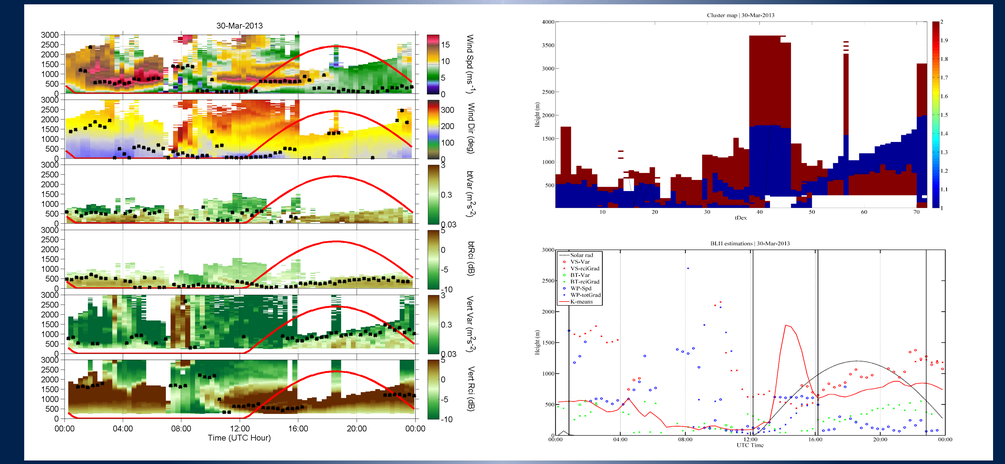
6.1 A good day

Transition that human eye identifies as BLH in the data is selected by both methods



6.2 A bad day

The chosen peak is not the good one, and the cluster analysis doesn't identify the BL air



Estimator	*Kmeans*	*VS var*	*VS RCI*	*BT var*	*BT RCI*	*WP spd*	*WP grad*
Successful days	13 (62%)	17 (81%)	9 (43%)	11 (53%)	10 (48%)	13 (62%)	7 (33%)

7. Conclusion and next steps

At this point, we have an estimation of BLH from each of the data (velocity variance, aerosol backscatter, wind), independently. But each one have its drawback (range, availability, accuracy). Mixing them intelligently could be a way to build a full time available and accurate estimator.
The clustering analysis method mixes the data from the beginning, but not yet the wind info. The main drawback is representativeness of the cluster.

- Add wind information (wind speed and wind direction) in clustering
- Investigate the convergence of the seeds (are the final clusters representative?)
- Improve the mechanism to choose the peaks
- Mix the 6 peak estimators into a single one
- Evaluate the algorithms on a extended dataset